MANAGING TREE MORTALITY LOCATION DATA WITH A DESK-TOP MINICOMPUTER[1/]

C. J. DeMars
Pacific Southwest Forest and Range Experiment Station
Forest Service, United States Department of Agriculture
Berkeley, California

ABSTRACT

Overlap in the color of faded foliage necessitates comparing individual trees in order to discriminate older from newer tree mortality detected on sequential color aerial photography. Predicting where previously detected tree mortality occurs on a newly acquired photograph permits comparison of dead tree locations. These comparisons are based on a search radius equal to $\bar{x} + 2.78\sigma$ of the accuracy of prediction have a 97.5% chance of finding previously recorded tree mortality. A two-dimensional affine transformation provides coefficients for scaling, and translation and rotation of axes that give accuracies of 3 to 10 m. in level terrain and 15 to 25 m. in mountainous terrain.

Data are digitized, stored, verified, and plotted using standard mini-computer components and a series of Hewlett-Packard language (HPL) routines to implement the computations.

Tree mortality information may be organized for ground-check sample selection by point locations or grid cell totals. Grid cell corners derived from true geometry maps may be transferred by prediction to the photo for use in the field.

1/ This research was supported in part by the U. S. Department of Agriculture, under the Expanded Southern Pine Beetle Research and Application Program, through the Forest Service's Southeastern Area, State and Private Forestry.

(1980. In Proceedings of remote sensing for natural resources, an international view of problems, promises and accomplishments [Sept. 10-14,]979, Moscow, Idaho], p. 69-77.)

I N T R O D U C T I O N

In the beginning God created a pine tree. On the second day he created a bark beetle to eat this tree, and on the third day the tree faded. On the fourth day the Lord created near-infrared wave lengths, having omitted them from the visible spectrum, and NASA took a photograph of the dying tree. On the fifth day a man went into the woods, with photograph in hand, to find that tree and explain the phenomonon to the multitude. On the sixth day, however, the man got lost, and after much wandering stopped to eat in an apple orchard. He has been resting ever since the seventh day, deep in the forest.

After awhile, the Lord looked down on the man with pity and sent to him for his salvation a computer. Because the man's sins were small, it was a minicomputer. What follows is a description of how the man used the machine to develop a data system and get himself out of the woods and back to grandma's house in time for tea.

S Y S T E M D E S C R I P T I O N

What is the system?

The photographic interpretation data system (PISYS) is a digitizer-computer-plotter combination for acquiring, comparing, locating, and filing mutually exclusive sets of point-location data derived from sequential color aerial photographs. The point locations represent the position of individual, or groups of, dead trees with foliage that has faded since the previous photographs were taken. Linear features such as roads, type lines, and boundaries may be represented satisfactorially as a series of discrete points.

PISYS does not attempt total automation of the photo-interpretation process. The efficacy of the system lies in its careful delineation of those tasks best performed by humans or more easily performed by machines. The human observer is highly capable of pattern recognition and value judgements in ambiguous situations, but is poorly equipped to compare the shape or color of two objects unless they are simultaneously viewed. It is relatively easy for a person with normal color and stereoscopic vision to learn to detect discolored blobs on a photograph and to separate those that are trees from those that are flat objects on the ground. Trees so identified may be counted and a cursor positioned over their location. With more experience, the tree species may be identified and an estimate made of where the tree intersects ground. If, however, a person is asked to determine whether the tree being examined was detected on the previous photographs, he can answer only after comparing the images as they appear on the two sets of photography. It is necessary to compare tree positions because of variation in the color of faded foliage of trees that have been attacked and killed by bark beetles at the same time, and the similarity of colors among those killed at different times.

By providing the interpreter with accurate, previously recorded information, he can quickly judge that a decision can be made based on this data or that the manual comparison method is required. If there is no record of a tree near the faded one being examined, it is a new tree. If there is record of a tree nearby

and only one is visible, it is an old tree. If several recorded trees are nearby, and it cannot be determined which one, if any, relates to the current tree, then the comparison method is required. With the previous history available, the interpreter becomes more efficient, and uses the slower cross-checking procedure only when necessary.

Machine-controlled performance of PISYS, on the other hand, is best applied to those functions that involve data capture, filing, totaling, summarizing, sorting, and plotting. Efficiency is gained by storing only points of interest rather than the entire photograph, pixel by pixel.

Who is the system for?

PISYS is designed for use by Regional and Area headquarters of the Forest Service's Forest Insect and Disease Management Units and Forest Insect and Disease Research Work Units at the Experiment Station, State Forest Insect Survey offices, and universities. The equipment involved is portable permitting use at those field locations equipped with a suitable computer data link.

When is the system useful?

The primary utility of PISYS is its ability to provide an accurate data base to define a population of points, unique to a particular date of photography, from which a reliable sample may be selected for ground-checking. Populations may be defined on a point (tree mortality spot) or area (grid cell) basis. The data base provides the means to accurately measure tree mortality trends, to formulate and test predictive models, and to conduct computer simulations of the possible results of various pest management strategies. The accuracy of the data base is enhanced by aiding the photo interpreter in decision-making. The system immediately captures, in a machine readable form, the decision made by the interpreter and provides an automated sequence of data storage, retrieval, and display for file verification and editing. This serves to ensure a high level of quality control over the data retained for further use. Automated file management provides convenient and accurate summarization and graphic display in a variety of formats.

The system can be used to select a random sample of points or grid cells to be ground-checked. PISYS can predict the location on photos of the corners of cells selected. The graphics produced by the system permit registration as overlays to the maps and photos. Plots for photos can include the predicted corner locations of selected grid cells. Ground plot boundaries and type lines may be transferred from one set of photography to another by this method.

How does the system work?

The system uses a mathematical model based on a scale factor, and translation and rotation of axes (Strang 1976) to map a set of X-Y coordinates from one two-dimensional space into another with a one-to-one correspondence (fig. 1). The model uses a pair of bivariate linear regressions of the form

$$Y' = b_0 + b_1X + b_2Y$$

to compute the X and Y coordinates of the transformed point position (Strang 1976). This is equivalent to an affine model (Wolf 1974).

The underlying assumption for this model is that the photo and map planes are parallel. Since only rarely are aerial photos truly vertical and terrain perfectly flat, it is necessary to determine the coefficients in a manner that minimizes the error.

A least squares regression fit of the coordinates of six well distributed control points, identified on the photo, on the coordinates of the matching control points, appearing on the map, is used to compute the coefficients for predicting map positions of other photo points. Conversely, a least squares regression fit of map points to photo points provides the coefficients for predicting photo positions of map points.

The system computes the map location of points identified on the aerial photographs and conversely; the photo location of points identified on the map. The system also computes the average accuracy of these predictions. Therefore, each point may be thought of as falling inside a circle with a radius of known probable error. In addition, labels and attributes associated with the point coordinates can be inputted. The system then stores, retrieves, and manipulates these data files. For a reference map that has been divided into a sampling frame of grid cell units, the cell address can be determined for any points mapped. The system operations are illustrated by a flow chart (fig. 2) and the equipment (fig. 3).

How accurate is the system?

The precision of the coefficients in fitting the control points is measured by computing the mean deviation between predicted and true positions. This information is used to check for errors in identification or coordinate data and to review control point selection; however, the system provides a biased estimate of the error in using the coefficients to predict the location of other points on the map. An unbiased estimate of that error is obtained by predicting the positions of a set of additional control points and computing their average deviation from the true positions. Since these points were not used in estimating the coefficients, they provide an independent estimate. To the extent that these points are distributed randomly over the photograph in a pattern similar to the points of interest with unknown map positions, the estimate is unbiased. The fitting error for each known point as well as the mean and standard deviation of the set of points is reported. From these statistics the interpreter may judge the reliance that may be placed on the data.

By increasing the number of control points over the minimum necessary to estimate the three coefficients, the mean fit error and variance of test points is reduced. The probability that a particular search will not find a previously recorded dead tree in the data lists is a function of the number of standard deviations used in setting the search radius. For photo-to-photo fits and four test points, the mean plus 2.78 σ and 3.75 σ give errors of 2.5% and 0.5%, respectively. The effect of varying the number of control points on the accuracy of fitting four test points was tested on sequential photography of 10-100 ha. plots in California using affine, affine with cross products, and conformal models (Wolf 1974). Terrain was evaluated as flat, if elevational changes were <1 dominate tree height; rolling, if 2-3 tree heights; and mountainous, of >4 tree heights. The average accuracy obtained for flat and rolling terrain combined was always <7±2 m. regardless of the number of control points or model used (table 1). This is not surprising because the assumptions are fairly well met. In mountainous terrain the error was 3 to 4 times larger (18±1 to 25±5 m.) than on flat or rolling terrain. Results with six control points were improved over those with four control points by 47%, 37%, and 15%, respectively, for affine, affine with cross products, and conformal models.

S Y S T E M   D O C U M E N T A T I O N

A more detailed description of the mathematics and computing algorithms, as well as the FORTRAN IV computer programs to implement the system in a batch processing mode on large computers, is being prepared for publication. The Hewlett-Packard (HPL) coded programs are available from the author.

L I T E R A T U R E   C I T E D

Strang, Gilbert. 1976. Linear algebra and its applications. 374 p. Academic Press, New York.

Wolf, Paul R. 1974. Elements of photogrammetry. 562 p. McGraw-Hill Co., New York.

Table 1. Accuracy in meters of applying transformation coefficients from two-dimensional models using four, five, and six control points to estimate coefficients for 10 flat-rolling and mountainous terrain plots.

Control points and model	Terrain: Flat-rolling			Terrain: Mountainous		
	$\bar{x}$	σ	radius[1/]	$\bar{x}$	σ	radius
4: Affine	6.6	1.7	11.3	21.7	7.4	42.3
Affine with XP[2/]	6.4	1.8	11.4	23.0	5.3	37.7
Conformal[3/]	6.7	2.0	12.3	25.1	5.0	39.0
5: Affine	6.9	1.9	12.2	19.0	1.7	23.7
Affine with XP	6.2	1.2	10.2	19.3	1.3	22.9
Conformal	6.8	2.1	12.6	23.0	2.5	30.0
6: Affine	6.5	1.8	11.5	17.4	1.0	20.2
Affine with XP	5.8	1.3	9.4	17.9	1.6	22.3
Conformal	6.6	2.3	13.0	21.9	2.0	27.5

1/ Radius for search of computer files with 97.5% chance of finding any previous record of tree mortality spot observed.

2/ Affine transformation with cross-product of XY.

3/ After Wolf (1974).

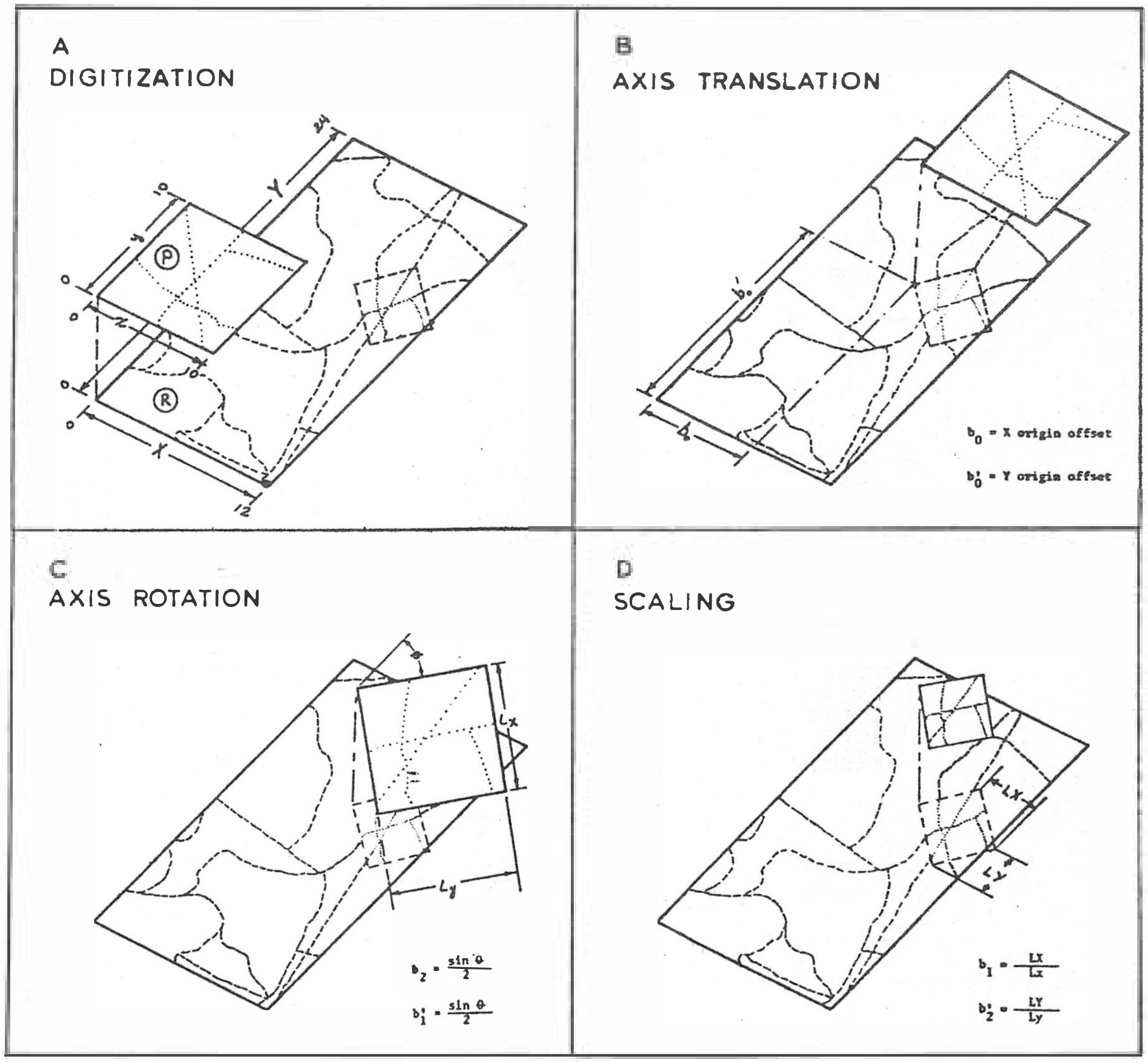

Figure 1. Effects of coefficients computed by the affine model in transforming the digitized coordinate lcoations of points on a large scale photograph to the corresponding position on a smaller scale map.

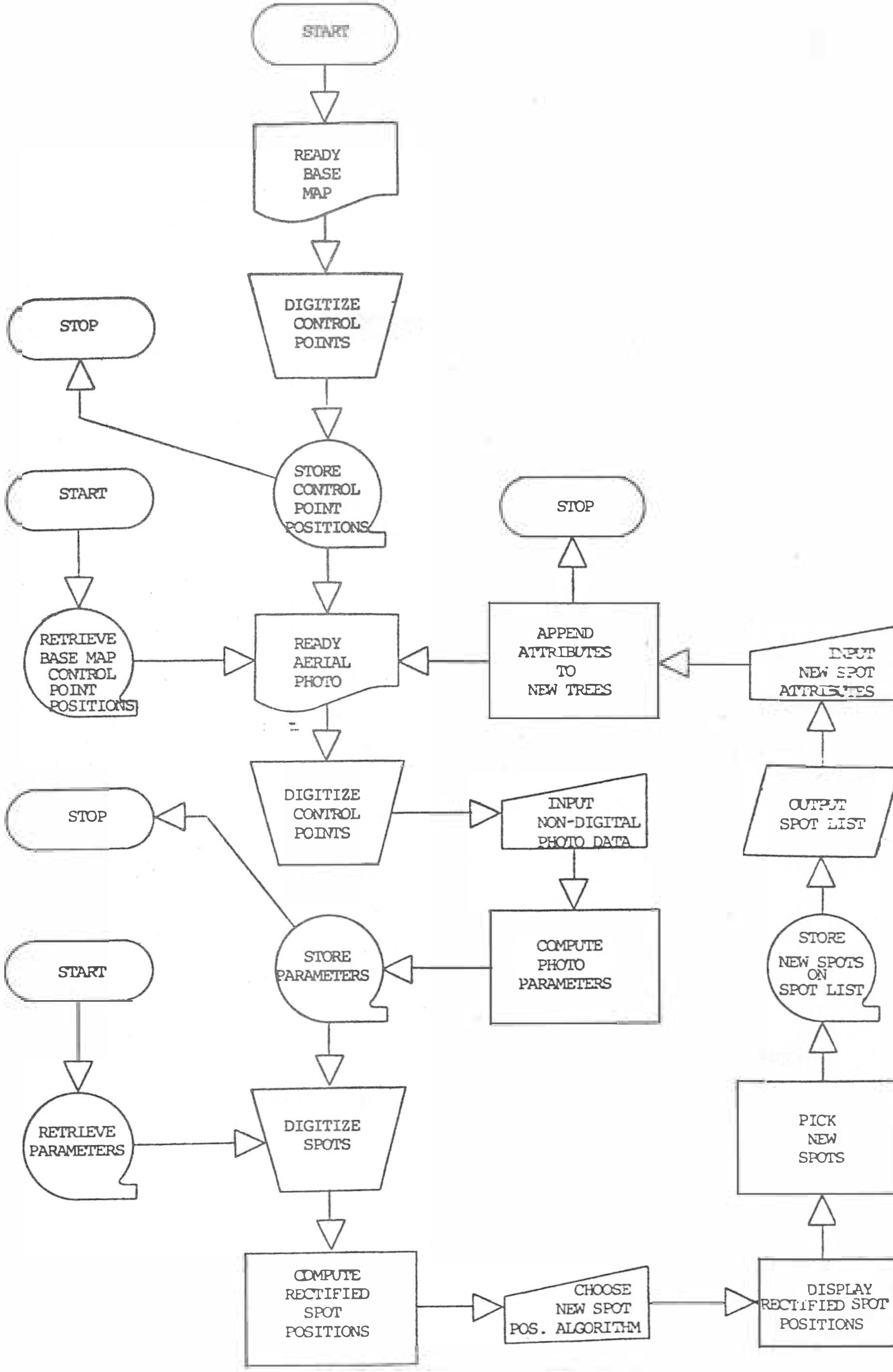

Figure 2. Flow chart of the sequence of operations performed by PISYS.

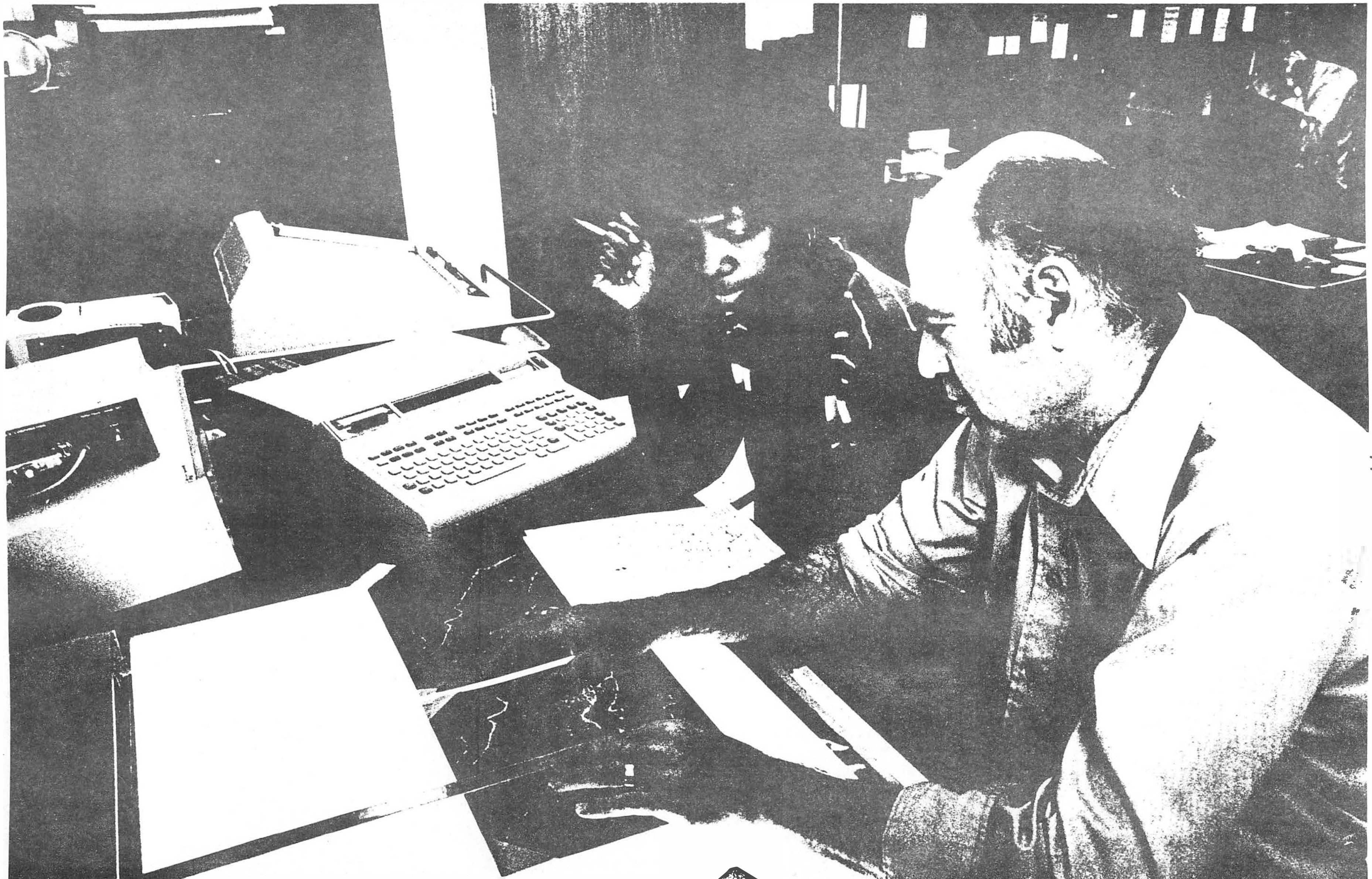

Figure 3. The PISYS system as implemented by the author. Photographs are viewed using an old Delph scanning stereoscope. Data are digitized with a numonic graphics calculator interfaced to a Hewlett-Packard 9825A Desk-top minicomputer. Graphic displays are prepared using the HP 9862A plotter.